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Study of evaporation and seepage losses from farm pond in saline area

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ABSTRACT : Farm ponds have traditionally been used as an economical and efficient way to retain water for livestock, watering and irrigation. Water harvesting through farm pond and utilization of conserved water for cultivated field is very crucial for promoting sustainable agriculture in Saline Area. The traditional concept of locating dug out structures at strategic locations was revived and promoted as farm ponds. To overcome the drought prone situation in drought affected districts of Vidarbha, constructions of number of dug out type ponds (water storage structures) for harvesting of excess rain water on farmers field is the best option available and is being implemented since last three years. Research Concluded evaporation and seepage loss component from unlined dug out type farm pond was found to be 58.82 and 12.60 cm, respectively during three months of water storage period (October to December). The evaporation component in Lined Black polyethylene was found to be in the range of 19.51 to 24.60 per cent of storage period. The one protective irrigation using harvested in runoff water in dug out farm ponds resulted in increases in the dry land productivity of Cotton and Gram crops to 47 to 55 per cent and 43 to 58 per cent, respectively.

KEY WORDS : Farm pond, Water harvesting, Saline area, Evaporation, Polythelene

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The Purna Valley of Vidarbha region is an east-west elongated basin with slight convexity to the south occupying part of Amravati, Akola and Bhuldhana district of Vidarbha and extends from $20^0 45'$ N latitude and 75^0 15' to 77^0 45' E longitude with east-west length of about 100-150 km having width of about 10 to 60 km covering an area of about 2.74 lakhs ha in 547 villages (Pal, 2004). The unique feature of salt affected soils of Purna Valley is that though the salinity and sodicity is widely reported in this tract, the use of well water, which is poor quality, makes the situation more problematic.

The farming practices adopted in saline tract of western Vidarbha is totally rainfed since ground water resources are not suitable for irrigation. The productivity in this area is totally dependent on amount and distribution of monsoon rainfall. Harvesting of rain water and reusing it for providing life saving irrigation to crops has thus become an urgent need of the hour for stabilizing and further improving the production potential of dryland farming in saline tract for the benefit of farmers under ongoing changing rainfall situation and recurring droughts.

To overcome the drought prone situation in drought affected districts of Vidarbha, constructions of number of dug out type ponds (water storage structures) for harvesting of excess rain water on farmers field is the best option available and is being implemented since last three years. Water stored in the ponds or reservoirs is subjected to loss by seepage and evaporation. The loss due to seepage is governed by the properties of soil forming the floor and the banks of the storage while evaporation loss is a function of the climate characteristics of the location of the storage. The data on seepage and evaporation losses from dug out type ponds (small water bodies) in saline tract areas is not available. Seepage and evaporation loss data needs to be quantified in saline tract of Vidarbha region so that maximum amount of harvested water can be made available for protective irrigation.

The harvested water in farm ponds is being used for providing life saving irrigation to dryland crops by lifting and applying to the fields. In the semi-arid region like Vidarbha, the evaporation rates from water storage structures are generally high due to high temperature, low relative humidity, and high wind speeds, To minimize the evaporation loss from

such small water harvesting structures in arid and semi-arid regions, scientist world over, have tried several types of anti-evaporants such as floating sheet cover of plastic membrane, polystyrene sheet, foamed wax blocks, plant residue, oil mulches, polyethylene oxides, gum mixtures and fatty alcohols (Dhruva Narayan *et al.*, 1997). There was not much success with these attempts. As yet, an efficient, economical and durable evaporation suppressant has not emerged from the research which can be used widely.

Large number of dug out type farm ponds (120) is constructed in Ghusar village of Akola taluka by State Agriculture Department which varies in design, dimensions and sizes. Both lined and unlined type dug out farm ponds are available in the study area and there is a need to quantify storage losses from farm ponds in saline tract region.

METHODOLOGY

Study area :

The study was carried out in Purna Valley of Vidarbha region where farming practices adopted in saline area of western Vidarbha is totally rainfed since ground water resources are not suitable for irrigation**.** The climate is characterized by relatively hot summer, and cold winter. In Akola taluka average annual temperature ranges from a high of 48^0C to a low of 10^0C. The overall climate can be classified as semi-arid tropical. The total average annual rainfall in Akola taluka is 751.52 mm. The village under the study received 655.10 mm annual rainfall during 2009 in 34 rainy days, out of which monsoon season (June to September) contributed 87 per cent. The village under the study received 1041.5 mm annual rainfall during 2010 in 38 rainy days, out of which monsoon season (June to September) contributed 89 per cent. The Ghusar village, agro-climatically falls under assured rainfall zone of Vidarbha region of Maharashtra.

Data acquisition :

There are about 120 dug out farm ponds constructed under the Prime minister Pakage and National Horticulture Mission Programme in Ghusar village of Akola taluka. During 2008-09 and 2009-2010, during 2008-09, only 27 ponds were constructed on farmers field while 93 farm ponds were constructed during 2009-10 under both the programmes as stated above. The dug out farm ponds constructed in the village under study are either constructed on-stream or off-stream and few of them are lined. The farm ponds constructed during 2008-09 and 2009-2010 were only considered for this study and from which 11 dug out type ponds were selected for study.

Climatic data :

The climatic weather data on minimum and maximum temperature, morning and evening relative humidity, bright sunshine hourse, wind speed, pan evaporation and rainfall collected at Meterological observatory of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and was considered for the study, Since the experimental site is 12 km away from the location of the observatory.

Seepage and evaporation loss measurement :

The water storage losses from dug out farm ponds were quantified by monitoring water level fluctuations in the ponds periodically weekly after the end of rainy season, when ponds are in mostly filled condition. The water storage losses so monitored in consists of seepage losses from sides and bottom of unlined ponds and evaporation from surface area. To seprate out from seepage losses and evaporation losses components from water losses recorded in the unlined dug out farm pond, water storage losses due to only surface evaporation from black polyethelene (400 micron size), lined dug out pond of same size was monitored. Water loss from unlined dug out type farm pond was monitored in four ponds of same size (30 m × 30 m × 3 m).Similarly for monitoring only evaporation loss components from dug out farm pond, three polyethylene lines ponds (pond number 4, 5 and 10) were monitored during 2009-

Table A : Details of selected dug out farm ponds in saline area of Ghussar village

Sr. No.	Name of farmers	Pond number	Location of farm pond	Size of farm pond (m)	Lined/Unlined
1.	Shivprasad S. Laharia	1	32	30 × 30 × 3	Unlined
2.	Sardar S. Laharia	2	33	30 × 30 × 3	Unlined
3.	Rajesh S. Laharia	3	37	30 × 30 × 3	Unlined
4.	Gunwant B. Wakode	4	107	82 × 26 × 3	Lined
5.	Rameshwar J. Pagrut	5	107	82 × 26 × 3	Lined
6.	Nilesh Raut	6	138	30 × 30 × 3	Unlined
7.	Dipak Prakash Raut	7	137	30 × 30 × 3	Unlined
8.	Shrikrushna W. Behare	8	898	30 × 30 × 3	Unlined
9.	Laxman W. Behare	9	820	30 × 30 × 3	Unlined
10.	Santosh S. Pagrut	10	847	82 × 26 × 3	Lined
11.	Damodhar Khadase	11	877	82 × 26 × 3	Unlined

10 and 2010-11.The Photographs of lined (82 m × 26 m × 3 m) and unlined (30 m × 30 m × 3 m) dug out farm ponds (Table A).

Utility of harvested water :

Utility of harvested rain water in dug out type ponds was recorded for the *Rabi* season at 2009-10 and 2010-11. The number of protective irrigation given by different farmers under study, area covered with available water resources, type of crops for which protective irrigation given and productivity obtained was recorded. The Productivity of dry land crops taken by adjoining farmers without protective irrigation was also recorded.

■ RESULTS AND DISCUSSION

The result of "Assessment of storage losses from dug out type farm pond in saline tract." The field data collected in respect of the storage losses from the experimental farm ponds and utility of harvested water during 2009 and 2010 were analyzed losses. The results of the analysis are presented in following heads.

Storage losses from dug out type farm ponds :

Water storage losses from dug out type farm ponds in saline tract area of Ghussar village was studied by monitoring stored water levels in lined and unlined ponds constructed on farmers field during 2009 by the state Agriculture Department under different development programmers. Water level observations were recorded on weekly basis in four unlined ponds of 30 m × 30 m × 3 m size, one unlined pond of 82 m x 26 m x 3 m size and three lined ponds of 82 m × 26 m × 3 m size during 2009 *Rabi* season. Water level observations in above farm ponds were also monitored in the next rainy season of 2010 except the unlined pond of 82 m × 26 m × 3 m size (Pond number 11) which was damaged during the rainy season of 2010. Since, the pond number 11 was constructed on stream due to large volume of stream flow rates due to incessant rains of 2010, the pond was completely damaged and water could not be collected in it that season.

Evaporation losses from lined dug out farm pond :

The weekly evaporation losses recorded from three lined ponds of 82 m x 26 m x 3 m size during 2009 and 2010 are given in Table 1, indicates that the weekly evaporation during 2009 and 2010 in general varies from 3.65 cm to 5.75 cm and 3.50 cm to 7.00 cm, respectively. The total evaporation during three month period are in general higher during 2010 than that of

Table 1 : Weekly evaporation losses from lined type of farm pond during 2009 and 2010

Met week	Evaporation losses (cm) during 2009				Evaporation losses (cm) during 2010			
	Pond number			Average, cm	Pond number			Average, cm
	4	5	10		4	5	10	
41	5.08	5.37	5.17	5.21	5.00	5.00	5.00	5.00
42	5.75	5.43	4.91	5.23	6.00	5.00	6.00	5.67
43	5.75	5.75	5.67	5.02	7.00	4.00	6.00	5.67
44	5.50	4.92	4.33	4.92	7.00	4.00	5.00	5.33
45	5.00	4.60	4.85	4.82	6.00	5.00	6.00	5.67
46	5.20	4.90	5.30	5.13	5.00	4.00	6.00	5.00
47	6.00	5.80	5.90	5.40	6.00	5.00	5.00	5.33
48	5.80	6.33	4.42	5.00	6.00	6.00	6.00	6.00
49	5.00	4.90	5.10	5.00	3.67	6.00	4.34	4.67
50	4.60	4.70	4.85	4.72	4.66	5.33	3.50	4.50
51	3.70	3.65	3.65	3.67	5.67	3.67	3.17	4.17
52	5.23	4.83	4.08	4.71	5.00	3.00	4.49	4.16
Total	62.61	61.18	58.23	58.82	67.00	56.00	60.50	61.17

Table 2 : Monthly evaporation losses from lined type of farm ponds during 2009 and 2010

Sr. No.	Month	Evaporation losses (cm) during 2009				Evaporation losses (cm) during 2010			
		Pond number			Average, cm	Pond number			Average, cm
		4	5	10		4	5	10	
1.	October	22.08	21.47	20.08	20.37	25.00	18.00	22.00	21.67
2.	November	22.00	21.63	20.47	20.35	23.00	20.00	23.00	22.00
3.	December	18.53	18.08	17.68	18.10	19.00	23.00	15.50	17.50
Total		62.61	61.18	58.23	58.82	67.00	56.00	60.50	61.17

2009 except from pond number 5, were reverse trent is recorded. This reduction of evaporation loss during 2010 in only 5 number pond might be due to change of crop from Gram (2009) to Cotton (2010) around the pond of Shri. R.J. Pagrut. The total evaporation loss during 2009 and 2010 ranges from 58.23 cm. to 62.61 cm and 56.00 cm to 67.00 cm, respectively during October to December.

Monthly evaporation from black polyethylene lined dug out type ponds (82 m x 26 m x 3 m) as given in Table 2, indicates that higher evaporation occurs in the month of October followed by November and December, which may be due to higher temperature prevailing in the month of October and reducing light hours in winter months (December).

The Multiple regression equation is fitted between average daily evaporation recorded during different meteorological weeks (41 to 52) and minimum and maximum temperature, morning and evening relative humidity, bright sunshine hours and wind speed during corresponding meteorological weeks of 2009 and 2010.The result of regression analysis are given in Table 2.

The water storage loss from unlined dug out type farm ponds 30 m × 30 m × 3 m size recorded at four different locations during 2009 and 2010 are given in Table 4 and 5, respectively.

The water weekly storage loss from four unlined ponds varies from 5.89 to 8.02 cm (Table 4) and 2.34 to 6.00 cm (Table 5) during 2009 and 2010, respectively. The total storage loss from October to December during 2009 and 2010 varies from 77.50 cm to 91.82 cm and 41.66 cm to 63.66 cm, respectively. The above results of water storage losses during 2009 and 2010, indicates that during 1st year of construction of ponds (2009), water storage losses are in general more than that of the 2nd year after construction (2010). The average water storage losses during October to December 2009 come out to be 82.10 cm and the same value during 2010 comes out to be 53.19 cm. The water storage losses from unlined dug out farm pond consist of both surface evaporation and seepage compmnents. The considerable difference in water storage loss (28.91cm) during first and second year of construction clearly indicates that the seepage component in first year of construction (2009) is quite high which subsequently reduces in 2nd year of the study period (2010).

Table 3 : Result of regression analysis

Sr. No.	Contents	Result
1.	Multiple regression	0.913
2.	R square	0.833
3.	Adjust R Square	0.775
4.	S.E.	0.358
5.	Observations	24

Table 4 : Weekly storage losses from unlined type of farm pond during 2009

Sr. No.	Meteorological weeks	Evaporation losses (cm) during 2009				
		Pond number				Average, cm
		2	6	8	9	
1.	41	7.08	8.02	6.71	6.14	6.98
2.	42	6.89	7.72	5.92	5.89	6.60
3.	43	7.10	7.35	5.95	7.20	6.90
4.	44	6.17	7.65	6.66	6.50	6.74
5.	Total (October)	27.23	30.73	25.24	25.72	27.23
6.	45	6.12	7.54	6.72	6.64	6.74
7.	46	6.06	7.62	6.75	6.58	6.75
8.	47	6.08	7.70	6.76	6.70	6.81
9.	48	6.11	7.73	6.79	6.74	6.84
10.	Total (November)	24.37	30.59	27.02	26.66	27.10
11.	49	6.20	7.68	6.85	6.75	6.87
12.	50	6.41	7.65	6.90	6.78	6.94
13.	51	6.52	7.60	6.93	6.50	6.89
14.	52	6.77	7.57	6.99	6.77	7.02
15.	Total (December)	25.90	30.50	27.67	26.80	27.27
16.	Total	77.50	91.82	79.92	79.18	82.10

Table 5 : Weekly storage losses from unlined type of farm pond during 2010

Sr. No.	Meteorological weeks	Evaporation losses (cm) during 2009				Average, cm
		Pond number				
		2	6	8	9	
1.	40	6.00	5.50	5.00	4.50	5.25
2.	41	6.00	5.50	5.00	4.50	5.25
3.	42	6.00	5.90	6.00	3.75	5.41
4.	43	6.00	5.85	4.28	4.00	5.10
5.	Total (October)	24.00	22.75	20.28	17.00	21.01
6.	44	6.00	4.85	4.10	3.25	4.55
7.	45	5.50	4.95	4.50	4.00	4.74
8.	46	5.00	5.00	4.00	4.00	4.50
9.	47	5.16	5.00	4.20	3.67	4.46
10.	Total (November)	21.66	19.80	16.60	14.92	18.25
11.	48	5.66	4.29	4.00	2.34	4.07
12.	49	4.67	4.00	3.08	2.51	3.56
13.	50	4.33	4.17	2.67	2.42	3.40
14.	51	3.34	3.33	2.50	2.47	2.91
15.	Total (December)	18.00	15.79	12.24	9.74	13.94
16.	Total	63.66	58.34	49.12	41.66	53.19

Table 6 : Saturated hydraulic conductivity of soil samples at different depths in dug out type farm pond

Farm pond number	Total depth of soil samples taken (m)	Range of hydraulic conductivity (cm/hr)
2	0.60 to 2.90	0.54 to 0.24
6	0.50 to 3.20	0.60 to 0.20
8	0.40 to 3.00	0.51 to 0.16
11	0.60 to 3.00	0.60 to 0.16

Table 7 : Weekly evaporation and seepage losses (cm) from dug out farm ponds during 2009

Sr. No.	Meteorological weeks	Evaporation losses (cm) lined ponds	Storage losses (cm) unlined pond	Seepage loss (cm)
1.	41	5.21	6.42	1.21
2.	42	5.23	6.41	1.18
3.	43	5.02	6.17	1.15
4.	44	4.92	6.07	1.15
5.	Total-October	20.37	25.07	4.70
6.	45	4.82	6.00	1.18
7.	46	5.13	6.25	1.12
8.	47	5.40	6.40	1.00
9.	48	5.00	6.00	1.00
10.	Total-November	20.35	24.65	4.30
11.	49	5.00	5.90	0.90
12.	50	4.72	5.70	0.98
13.	51	3.67	4.50	0.83
14.	52	4.71	5.60	0.89
15.	Total-December	18.10	21.70	3.60
	Grand Total	58.82	71.42	12.60

Evaporation and seepage losses from dug out type farm pond:

The quantification evaporation and seepage losses from dug out type farm pond in Ghussar village was done by monitoring the water level fluctuation in unlined and lined farm ponds of similar size (82 m × 26 m × 3 m) on weekly basis starting from October 2009 till December 2009. Weekly water loss observations from both three lined and one unlined farm ponds are given Appendix-III. The water loss in three lined ponds is due to only surface evaporation, where as the water loss from unlined pond is due to both surface evaporation and seepage. The average evaporation loss from lined ponds and the water storage loss from unlined pond during 41 to 52 meteorological weeks are given in Table 7.

The difference between these two types of losses in different meteorological weeks indicate that seepage losses that occured in unlined pond. The result of quantified evaporation and seepage losses during 2009, indicate that weekly values of evaporation and seepage loss ranges from 3.67 cm and 5.23 cm and 0.83 cm to 1.21 cm, respectively in different meteorological weeks. The monthly evaporation loss during October to December ranges from 18.10 cm to 20.37 cm and seepage losses ranges from 3.60 cm to 4.70 cm (Table 7).

The total evaporation and seepage loss from dug out type farm pond was found to be 58.82 cm and 12.60 cm, respectively. The percentage of seepage losses was found to be 21 per cent of evaporation during the three months storage period.

The per cent of volume of water lost from the farm ponds during October to December, over the total storage capacity, in unlined and lined ponds varies in the range of 14.93 to 22.21 per cent and 19.51 to 24.96 per cent, respectively (Table 8), indicates that the average volume of water lost during three months storage period (October to December) in unlined and lined farm ponds comes out to be 18.73 and 22.70 per cent, respectively (Table 8). There it can be concluded that in saline tract area or deep clayer soils, on an average 21 per cent of stored volume of harvested water is lost till its utilization as protective irrigation.

Utility of harvested pond water :

The utility of runoff water harvested in dug out type farm ponds at different farmer's field was monitored during 2009 and 2010 and results are discussed in following head.

Quality of harvested water :

The quality of harvested runoff water in dug out farm ponds during the rainy season of 2009 and 2010 was tested by analyzing the water samples for pH values and electrical conductivity. The results of chemical analysis of water samples given in Table 9, which indicates that, the pH of water samples varies from 7.42 to 8.50 and 7.95 to 8.34 during 2009 and 2010, respectively. The pH values of harvested water (Table 9)in dug out farm ponds is slightly alkaline in nature, which can be used for protective irrigation since,the pH values of ground water is quite high (11.50) and is not suitable for irrigation (Bharmbe *et al.*, 2004). The electrical conductivity of water samples during 2009 and 2010 varies from the ranges of 0.28 to 0.42 dsm^{-1} to 0.31 to 0.55 dsm^{-1}, respectively. The electrical conductivity of harvested water rumoff water is on slightly higher side of the good quality water (0.25 dsm^{-1}), but the

Table 8 : Water losses from lined and unlined dug out farm ponds in three month storage period (October to December)

Sr. No.	Farm pond number	Size of farm pond (m)	Total storage volume (m^3)	Volume of water loss (m^3)	Per cent storage losses
1.	2 (Unlined)	30 × 30 × 3	1971.00	384.84	19.53
2.	6 (Unlined)	30 × 30 × 3	1971.00	352.21	22.21
3.	8 (Unlined)	30 × 30 × 3	1971.00	295.81	18.27
4.	9 (Unlined)	30 × 30 × 3	1971.00	250.07	14.93
			Average water loss in Unlined farm pond (m^3)		18.73
5.	4 (Lined)	82 × 26 × 3	5019.00	979.03	19.51
6.	5 (Lined))	82 × 26 × 3	5019.00	955.18	23.64
7.	10 (Lined))	82 × 26 × 3	5019.00	1014.51	24.96
			Average water loss in Lined farm pond (m^3)		22.70

Table 9 : Effect of protective irrigation on soil health

Sr. No.	Farm pond number	February 2010		November 2010		March 2011	
		pH	EC, (dsm^{-1})	pH	EC, (dsm^{-1})	pH	EC, (dsm^{-1})
1.	3	8.64	0.30	8.25	0.22	8.67	0.28
2.	4	8.43	0.26	8.28	0.20	8.50	0.22
3.	6	8.79	0.32	8.06	0.22	8.85	0.30
4.	8	8.43	0.30	8.12	0.21	8.51	0.23
5.	11	8.65	0.28	8.02	0.22	8.52	0.25

water with an electrical conductivity in the ranges of 0.25 to 0.75 dsm^{-1} can also be used for irrigation with precautionary measures or with limited used (Patil *et al.*, 2000).

Effect of protective irrigation of soil :

To study the effect of protective irrigation using harvested runoff water on saline sodic soil of Purna valley, the soil sample from five farmers were taken after the harvest of *Rabi* crop during 2009 (month of February 2010), after the end of rainy season of 2010(November 2010), and after harvested of *Rabi* crop of 2010 (March 2011).The results of chemical analysis of soil samples as given in Table 10, shows that the high PH and electrical conductivity of soil sample after harvest of the *Rabi* crop reduces to normal level in the month of November due to leaching of salts in rainy season. The result in Table 13, showes that salt concentration in crop root zone layer increases after protective irrigation due to upwared movement of salts which reduces after leaching after the rainy season and hence, it can be concluded that the practice of protective irrigation is not harmful in saline tract area.

Summary and conclusion :

The observations and the results of the study show that farm pond is an effective technology for harvesting and recharging the runoff there by providing water for protective irrigation. From the results obtained in present study, following conclusions are drawn.

- The evaporation ane seepage loss component from unlined dug out type farm pond was found to be 58.82 and 12.60 cm, respectively during three months of water storage period (October to December).
- Evaporation losses from Lined dug out type farm pond were found in the range of 58.23 to 61.18 cm during October to December. The evaporation component in Lined Black polyethelene was found to be in the range of 19.51 to 24.60 pre cent of storage period.
- The water storage losses from Unlined dug out farm ponds were found to be reduced from 1st year construction to the 2nd year. The average water storage loss during 2nd year of construction was found to be 14.93 to 22.21 per cent of storage capacity.
- The one protective irrigation using harvested in runoff water in dug out farm ponds resulted in increases in the dry land productivity of Cotton and Gram crops to 47 to 55 per cent and 43 to 58 per cent, respectively.
- The more number of protective irrigations (two to three) resulted in increasing the productivity of Cotton crop to the tune of 13 to 46 per cent other tha one protectve irrigation.

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REFERENCES

Anonymous (2009). Economic survey of Maharashtra (2009-10), Directorate of Economics and Statistics, Planning Department, Gov. of Maharashtra, Mumbai. Annual report: 3.

Arnold, J.G. and Stockle, C.O. (1991). Simulation of Supplemental Irrigation On-Farm Ponds. *J. Irri. & Drain. Engg.*, **117**(3) : 408-424.

Beasley, R.P. (1952). Determining the effect of topograpHy and design on the characteristics of farm ponds, *J. Agril. Engg. Nov.*, 702-704.

Bhandarkar, D.M. (2010). Rain water harvesting and recycling technology for sustainable agriculture in Vertisols of high rainfall;National seminar on Engineering Agriculture for Evergreen Revolution,ISAE- AP Chapter. September 24-25.

Carreker, J.R. (1945). Costruction and management of farm ponds, *J. Agril. Engg*., Feb.: 63-65.

Chittaranjan, S. (1982). Rain water harvesting and recycling, Indian *J. Soil Coserv*., **9**(2-3) : 100-106.

Dhanapal, G.N., Harsha, K.N., Manjunatha, M.H. and Ramachandrappa, B.K. (2010). Rain water management for maximization of farm productivity and conservation of natural resources in Alfisols of Karnataka. *All India Co-ordinated Research Project on Dryland Agriculture,* **1** : 340-346.

Dhruva Narayana *et al.* (1997). Watershed management : ICAR, New Delhi (INDIA).

Gorantiwar, S.D., Dhotre, R.S. and Dahiwalkar, S.D. (2008). Effect of percolation tank in augmenting the ground water recharge souvenir. National seminar on "Soil, water conservation and crop management technology under rainfed Agriculture" ZARS, Solapur, pp. 10.

Grewal, S.S., Luneja, M.L., Debey, L.N. and Chandrapa, M. (1982). Effect of some soil and site properties on seepage losses from harvested runoff water in small storage reservoirs. *J. Agril. Engg.,* **19**(4) : 63-70.

Howard Matson (1943). More farm ponds needed, *J. Agril. Engg*., **24** : 380-384.

Israelsen, O.W. and Hansen, V.E. (1962). (Third Edn.) Irrigation Principle and Practices. John Wiley and Sons, Inc. N.Y.

Jackson, M.L. (1973). *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., NEW DELHI (INDIA).

Khan, M.A. (1992). Evaporation of water from free water surface climatic influence. *Indian J. Soil. Conservation,* **20** (1 & 2) : 26-27.

Man, H.S. and Ramana Rao, B.V. (1981). Rain water harvesting, management and its implications. *Indian J. Soil Cons.,* **9**(2-3): 77.

Panigrahi, B. and Panda, S.N. (2003). Optimal sizing of on-farm reservoirs for Supplemental irrigation. *J. Irrigation & Drainage Engg., ASCE,* **129**(2) :117-128.

Pal, D.K. (2004). Genesis of sodic black soils (Vertisols) of central India. Souvenir state level seminar on "Development of soil Science 2004", Akola chapter of Indian Society of Soil Science.Deptt. of Agril. Chemistry and Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) INDIA.

Sastry, G., Hussenappa, V. and Bansal, R.C. (1980). Farm ponds for assured protective irrigation for *Rabi* crops in Doon valley. *Indian. J. Soil Cons.,* **8**(11) : 35-36.

Sastry, G., Hussenappa, V. and Bansal, R.C. (1983). Farm ponds and their influence on flood retardance. *Indian J. Soil Cons.,* **11**(1-3): 54-57.

Sastry, G., Joshi, B.P. and Singh, Gurmel (1982). Structural measures for efficient control of seepage from dug out farm ponds. *Indian J. Soil Conservation,* **10**(2-3) : 120-123.

Sastry, G. and Mittal, S.P. (1987). Water harvesting and recycling Engineering aspects. *Indian J. Soil Conservation,* **15**(3): 17-22.

Sastry, G. and Singh, Gurumel (1993). Water harvesting and recycling Engineering aspect. *Indian J. Soil Conservation,* **21**(2): 40-45.

Sharda, V.N. and Shrimali, S.S. (1994). Water harvesting and recycling in Northern hilly area. *Indian J. Soil Conservation,* **22**(1-2) : 84-93.

Singh, Gurmel (2004). Manual of soil and water conservation practices. *Oxford & IBH Publishers,* New Delhi : 144.

Singh, R.P. and Subha Reddy, G. (1987). Resource management in a rainfed watershed. *Indian J. Soil Cons.,* **14**(3) : 52-58.

Srinivasulu, R., Osman, M., Krishna Murthy, V., Rao, K.V., Prasadand, K.L. and Narsimulu, B. (2010). Rainwater harvesting for drought proofing and productivity enhancement of FCV tobacco in south coastal Andhra Pradesh. *All India Co-ordinated Res. Project on Dryland Agric.,* **1** : 349-352.

Varma, H.N., Parihar, S.S. and Singh, Ranjodh (1984). Feasibility of storage of runoff in dug out ponds and its use for sullimental Irrigation in Punjab. *Indian J. Soil Conservation,* **12**(1) : 31-36.

Wagh, R.G., Wankhade, D.M. and Sawake, D.P. (1996). Role of Engineering techniques in increasing agricultural productivity. Farm pond technology for sustainable watershed management in Kokam region; Dec. (5-6):1-6

WEBLOGRAPHY

Pandey, P.K., Panda, S.N. and Panigrahi, B. (2006). Sizing on-farm reservoirs for crop-fish integration in rainfed farming systems in Eastern India. *Biosyst. Engg.,* **93**(4) : 475-489. (Available online : *http://www.sciencedirect.com*).

Srivastava, R.C. (2001). Methodology for design of water harvesting system for high rainfall areas. *Agric. Water Mgmt.,* **47**: 37-53. (Available at *www.elsevier.com /locate/agwat*).